

Paralleled Fuzzy Time Series and Genetic Algorithm Prediction

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Abstract—Paralleled Fuzzy Time Series(FTS) and Genetic algorithm(GA) prediction intends to bring these algorithms together to create a prediction model over time based events, while leveraging the MapReduce paradigm to enable parallel execution. Fuzzy Time Series is a algorithm that allows prediction by developing a model based on historical time based events. Genetic Algorithm emulates natural selection, such that we can improve the forecasts of a given prediction model. This process is run till the prediction converges sufficiently with the training data.

Index Terms—Fuzzy Time Series, Genetic algorithm, MapReduce



1 INTRODUCTION

ACCURATELY forecasting results for a given use case is always a challenge. It depends on multiple variables, there are exceptions which are not the norm that occur in everyday life and all related data for the given event may not be available.

An algorithm can make “as close to the truth” prediction, if it has sufficient historical data and it makes sense and relates the available data to the pattern of occurrences of that event. Weather forecasting, Election predictions, Stock market analysis and recommendations are few of the numerous examples that we see in everyday life, where prediction models are effectively used.

In this project, we intend to use Fuzzy Time Series (FTS) [1] and Genetic Algorithm (GA) [5] prediction models and translate them into MapReduce paradigm for reliable, accurate and efficient forecasting of time based events.

The novelty of this implementation is to provide an end-to-end solution by bringing together FTS, GA and MapReduce. FTS and GA being used in conjunction should improve prediction results, while MapReduce should improve running time as well as increase the amount of data ingested.

2 RELATED WORK

Fuzzy Time Series (FTS) [1] is a prediction model that has proved its ability to forecast in numerous use cases, such as tourism [2], enrollments [3], temperature [4] and many more.

Holland’s Genetic algorithm [5] has also been successfully been used in multiple prediction examples [6], [7], [11] and also in conjunction with FTS [8]. Genetic algorithm has also been run as MapReduce to solve the OneMax problem [10].

3 ARCHITECTURE

For the purpose of implementation of our Hybrid Model we plan to predict the time-based events. As an input to our prediction model we have used the data pertaining to number of events per year for the previous years as our statistical data input.

The architecture is divided into three modules data ingestion, prediction and data visualization. This is as shown in *Figure 1*.

3.1 Data Ingestion

This phase will allow a configurable way of parsing the input data. Initially data will be

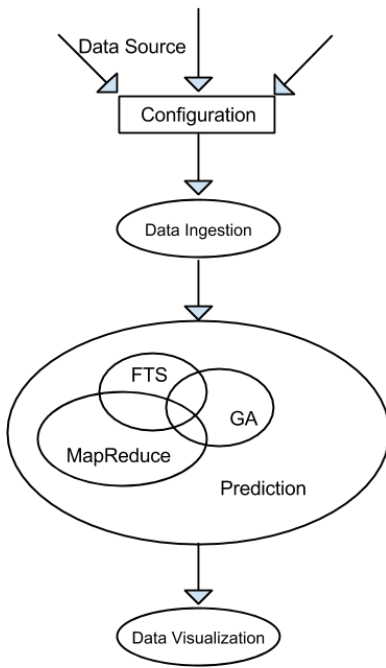


Fig. 1. Architecture of the implementation

read from a statistical data source such as publicly available data sets relevant to our prediction model. We have processed the data by application of MapReduce Paradigm so as to fine tune the data as per the input specification of GA+FTS Hybrid Prediction Model.

3.2 Prediction

The prediction module involves implementation of GA+FTS hybrid model on the incoming data from our data set. The subsystems for this model are explained below:

3.2.1 Genetic Algorithm (GA)

GA mimics the evolutionary principle of Survival of the Fittest. GA can be defined as a set of computational methods that are inspired by evolutionary biology such as mutation, selection, inheritance and crossover that can be used to find solutions to optimization problem. The first step of GA is to generate a random population of possible solution which correspond to a single generation. After this fitness value of every solution is calculated and multiple solutions are selected on basis of their fitness levels to generate a new generation.

This process is carried on iteratively till a point of convergence is reached where there is no significant improvement in a generation over previous generation.

3.2.2 Fuzzy Time Series (FTS)

In our prediction model FTS is basically used as a fitness calculator that is to calculate correctness of prediction for each individual solution as a function of Root Mean Square Error (MSE). This is done by dividing the input data for time bound event into even and equal lengths of interval and then random selection of individuals that are product of GA iteration.

Thus the working of our hybrid GA+FTS prediction model can be visualized as combination of two functionalities where GA is used to improve correctness of each generation over previous generations and FTS is used as a fitness calculator to check the correctness of prediction in terms of mean square error.

3.3 Data Visualization

The result data visualization phase will use the prediction model results and display them in various output formats in order to easily understand and visualize the results.

4 DESIGN STEPS

4.1 Algorithm

The algorithm for this project:

Step 1: Read the training data which in this case will be time based events.

Step 2: Find the maximum and the minimum values of the training data and compute the Universe of Discourse.

Step 3: Create the first generation of Genetic Algorithm which will be a set of randomized individuals. Each of the individuals will be within the Universe of Discourse.

Step 4: Create the division of the generation data which can be used in the MapReduce model.

Step 5: The mapper task will apply Fuzzy Time Series Algorithm using the training data and GA population. This will make prediction for each individual and fitness value for each of

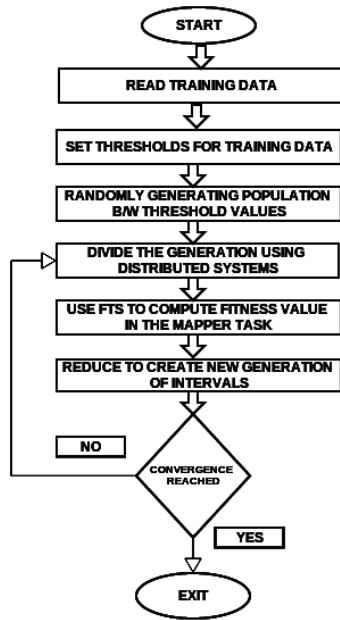


Fig. 2. Flowchart

them will be calculated.

Step 6: The reducer task will perform the selection, cross-over and mutation operations of GA based on the fitness value calculated by the mapper task. Thus, a new generation of individuals will be created.

Step 7: Repeat Steps 4 through 6 until the convergence point is not reached.

4.2 Flowchart

Figure 2 is the flowchart for this implementation

5 MODULES

There are three major modules namely data ingestion, prediction and data visualization.

5.1 Data ingestion

Figure 3 shows the interaction diagram of the Data Ingestion Module.

Data ingestion is used to consume raw data and produce output which will serve as the input to the prediction module. We have used MapReduce model to parse and raw data and generated the desired input. In this module we have collected time based data which is

readily available. For example, the data format will be month wise data for the events for specific region starting from year 1971. The data parser module will use MapReduce paradigm to giveout as year wise format along with the minimum and maximum value from same.

The MapReduce framework operates on $\langle \text{key}, \text{value} \rangle$ pairs, that is, the framework accepts the input to the job as a set of $\langle \text{key}, \text{value} \rangle$ pairs and produces a set of $\langle \text{key}, \text{value} \rangle$ pairs as the output of the job, in different types. The $\langle \text{key}, \text{value} \rangle$ pair here will be $\langle \text{year}, \text{no. of events} \rangle$. The function of Maps are to transform individual tasks that transform input records into intermediate records. Output of data maps, that is transformed intermediate records do not need to be of the same type as the input records. Reducer reduces a set of intermediate values which share a key to a smaller set of values. Sorted output of the mappers will be the input to reducer. The output of the reducer will be the sum of all events in a particular year.

5.2 Prediction

Figure 4, Figure 5, Figure 6, and Figure 7 are the class and interaction diagrams of the Prediction module.

Prediction module will include implementation of FTS and GA algorithms in the MapReduce paradigm. With the output from the data ingestion module, the minimum and maximum value as 440 and 1067. The universe of discourse $U = [D_{\min} \ D1, D_{\max} + D2]$, where D_{\min} and D_{\max} denote the minimum events and the maximum events at particular region shown in Figure 8, and $D1$ and $D2$ are two proper values.

The universe of discourse U will be divided into several even and equal length intervals. Here we have selected $D1$ as 40 and $D2$ as 33. Then we will generate population between threshold values which will be our first generation.

FTS is used as a fitness calculator which calculates the correctness of prediction for each individual as a function of Mean Square Error

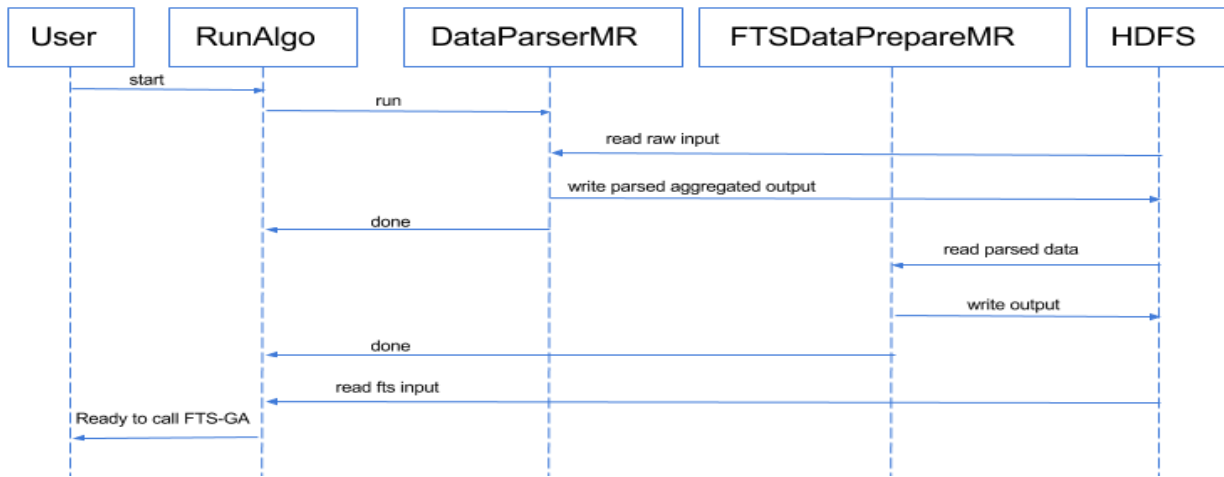


Fig. 3. Data Ingestion Interaction Diagram

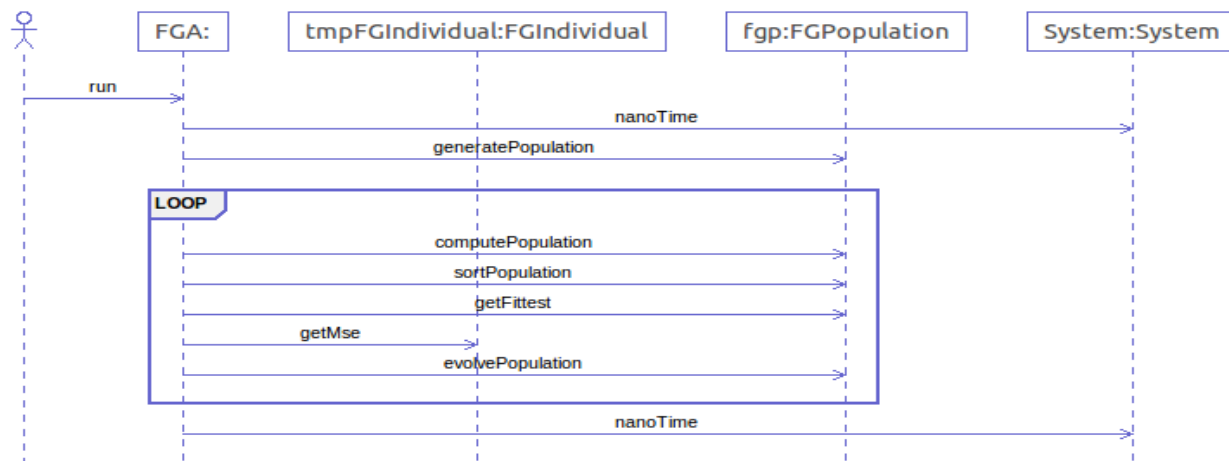


Fig. 7. Prediction module Interaction diagram

(MSE). FTS fuzzifies the historical data of the time-based events and generates fuzzy logical relationships based on the order. GA will be used to improve correctness for each generation over the previous generation by making use of GA operators which use the calculated fitness values. The calculated MSE value of each derived chromosome obtained in the new generation, and the same cycle is again implemented till a point of convergence is reached. In this case, the fittest individual will be the one having the lowest mean square error. If the minimum mean square error doesn't change over subsequent generations then the convergence point of the Genetic Algorithm is reached. Fig. 5. is the output of mean squared error between predicted and actual values.

5.3 Data Visualization

There are many different types of tools both web based and desktop based which will be very helpful for data visualization. We are exploring the use of Chart.js, Play framework and <https://plot.ly/> (web based tool) to showcase our results.

Chart.js uses the HTML5 canvas element. Chart.js is supported in all modern web browsers, it is javascript based and is lightweight. Play framework is web application framework built using Scala. It is asynchronous and lightweight.

Plotly is web based tool in which we can upload data to create and style charts with Plotly's online spreadsheet. Using Plotly Figure 10 is

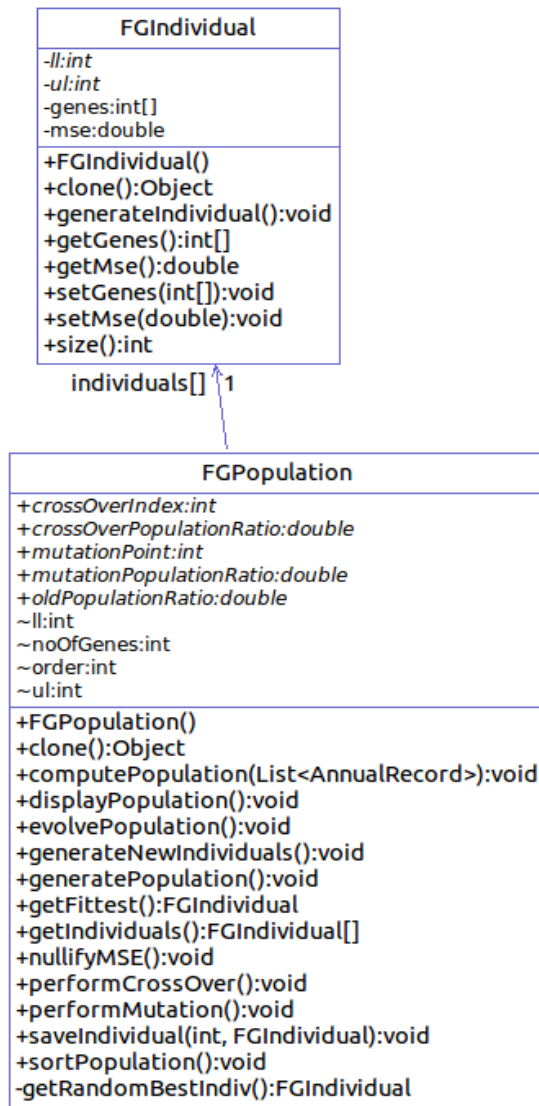


Fig. 4. Prediction module Class diagram - 1

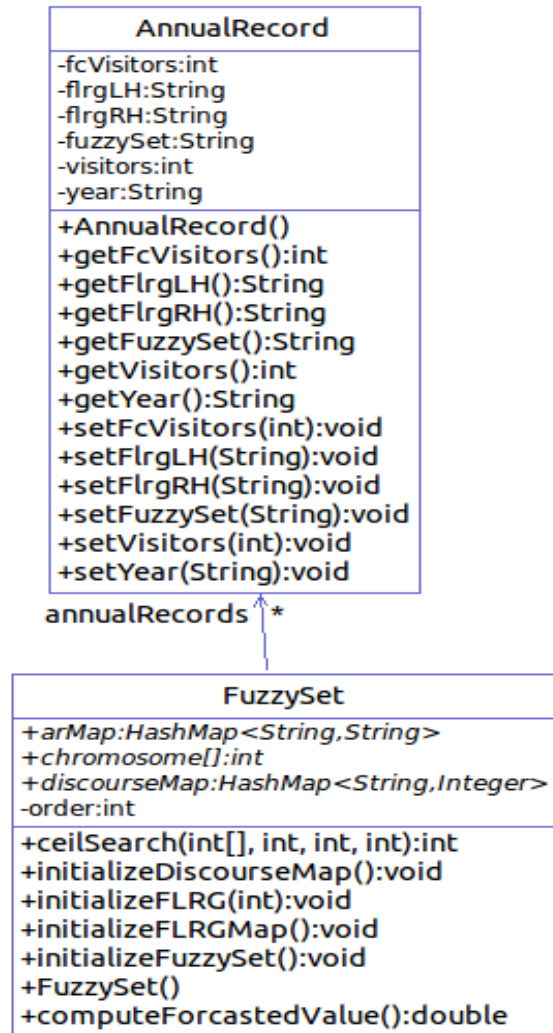


Fig. 5. Prediction module Class diagram - 2

generated, which is the reduction of MSE over generations.

6 RESULTS

The two main metrics for testing our forecasting models will be accuracy and running time. Higher accuracy would be indicated by comparing forecasted results with historical data, that is a lower Mean Squared Error between predicted and actual data sets.

Another result that we intend to achieve is significant drop in running time by implementing the same in distributed/parallel (Hadoop Framework) manner over normal sequential manner.

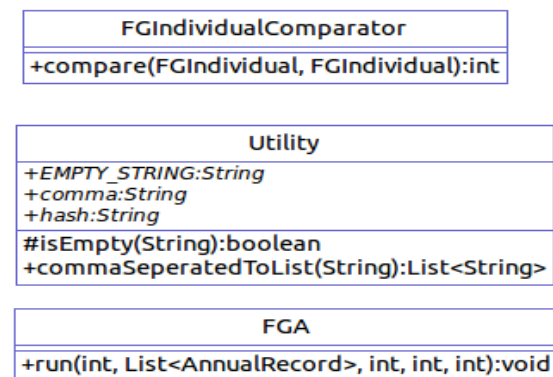


Fig. 6. Prediction module Class diagram - 3

1971	1025
1972	512
1973	1005
1974	852
1975	440
1976	502
1977	775
1978	465
1979	795
1980	970
1981	742
1982	635
1983	994
1984	759
1985	883
1986	599
1987	499
1988	590
1989	911
1990	862
1991	801
1992	1067
1993	917
Min	400
Max	1100

Fig. 8. Output of Data Ingestion

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Generation : 85 => 338.6084406314806
Generation : 86 => 338.60841965705004
Generation : 87 => 338.6083991648058
Generation : 88 => 338.6083791383092
Generation : 89 => 338.6083595618604
Generation : 90 => 338.6083404204574
Generation : 91 => 338.60832169975754
Generation : 92 => 338.60830338604177
Generation : 93 => 338.60828546618126
Generation : 94 => 338.6082679276057
Generation : 95 => 338.60825075827427
Generation : 96 => 338.6082339466477
Generation : 97 => 338.60821748166256
Generation : 98 => 338.60820135270717
Generation : 99 => 338.60818554959855
Generation : 100 => 338.6081700625609

```

Fig. 9. Output of Mean Square Error over generations

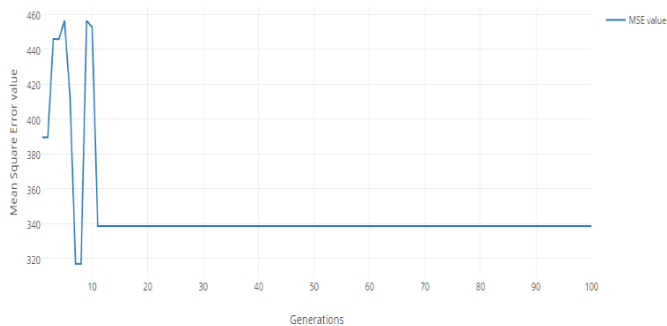


Fig. 10. Reducing Mean Squared Error over the generation

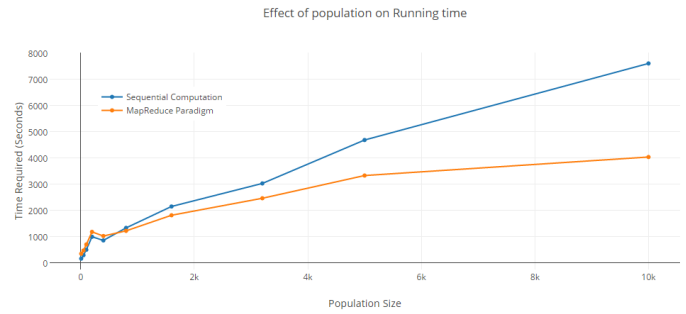


Fig. 11. Mock up of Speedup using MapReduce

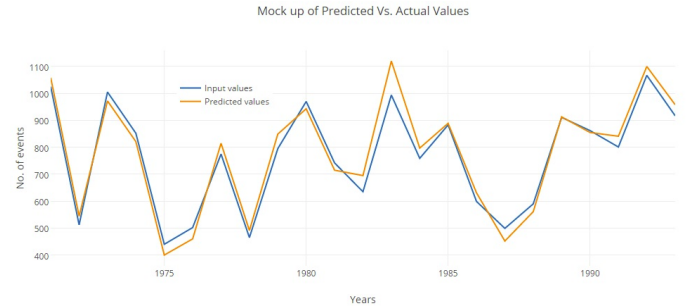


Fig. 12. Actual versus Mock Predicted values

Fig. 6. shows the expected differences in running time when the GA+FTS module is used in sequential manner and the same model being used by making use of MapReduce Paradigm. The results were generated on an Intel Core i3 @1.90GHz X4, 64 bits, 4GB RAM. We have observed some trends which are as follows, as number of intervals in the universe of discourse are increased, the MSE tends to decrease and as the order of fuzzy logical relationships increases, the MSE will decrease.

7 PROJECT MANAGEMENT

Table 1 list the major milestones planned in the project and the progress made for each of these milestones.

Table 2 lists the workload distribution of each of the individual team members. The tasks marked in green have been completed, the tasks mark in yellow are in progress while the tasks marked in red are proposed.

Table 3 describes our proposed working schedule for future weeks and how our team plans to complete the deliverable that needs

Sr.No	Milestones	Status	Comments
1.	Evaluate various parallel systems for project selection	Completed	Prediction of Time Based Events finalized as the project topic
2.	Study Genetic algorithm, Fuzzy Time Series and collection of various study material related to our topic	Completed	NA
3.	Project Proposal	Completed	NA
4.	Implement Phase 1: Data Ingestion Module	In Progress	Major portion of work (95 %) completed in this module. Exploring some further refinements that can be added to this module
5.	Implement Phase 2: GA+FTS Hybrid Module	In Progress	Almost (70 %) of the work is completed. Working on how to adapt this module in MapReduce Paradigm
6.	Implement Phase 3: Result Visualization	In Progress	Various tools for this Module have been explored. Working on how to integrate this module with the phase 2. (60 % complete)
7.	Midterm Project Deliverable	Completed	NA
8.	Integration of all the phases	In Progress	A working module consisting of all the phases has been implemented. Final Integration will be done once work on all the phases is complete
9.	Output Generation	In Progress	Some preliminary results have been generated. Once the entire integration is completed the output generation will be done to get all expected results. (30 % complete)
10.	Testing and Bug Fixes	Proposed	Once we have a complete running model we will implement this phase
11.	Final Presentation and Demo	Proposed	NA

TABLE 1
Current Status

Sr.No	Ankit	Preethu	Sumeet	Shantanu
1.	Evaluate various parallel systems	Evaluate various parallel systems	Evaluate various parallel systems	Evaluate various parallel systems
2.	Conduct study and collect material for GA	Conduct study and collect material for FTS	Conduct study and collect material for GA	Conduct study and collect material for FTS
3.	Explore various data sources to be used as input	Explore various data sources to be used as input	Explore various data sources to be used as input	Explore various data sources to be used as input
4.	Prepare Proposal Paper	Prepare Proposal Paper	Prepare Proposal Presentation	Prepare Proposal Presentation
5.	Understand Working of GA+FTS model	Understand Working of GA+FTS model	Understand Working of GA+FTS model	Understand Working of GA+FTS model
6.	Implement GA+FTS model phase	Implement Data Ingestion Phase	Implement Result Visualization Phase	Implement Result Visualization Phase
7.	Integration	Integration	Integration	Integration
8.	Output generation and analysis	Output generation and analysis	Output generation and analysis	Output generation and analysis
9.	Prepare Mid Term Project Paper	Prepare Mid Term Project Presentation	Prepare Mid Term Project Paper	Prepare Mid Term Project Presentation
10.	Testing	Testing	Testing	Testing
11.	Final Presentation and demo	Final Presentation and demo	Final Presentation and demo	Final Presentation and demo

TABLE 2
Individual Plan of action

Week #	Plan of Action	Task
Week 1	Completion of work for each individual phases	Complete fine tuning of Data Ingestion Phase, Implement the GA+FTS module in MapReduce paradigm, Finalize the Result Visualization Method to be used for output generation
Week 2	Completion of work for each individual phases and also coordinate on paper presentation for PREGEL	Complete fine tuning of Data Ingestion Phase, Implement the GA+FTS module in MapReduce paradigm, Finalize the Result Visualization Method to be used for output generation, Work on PREGEL presentation and paper
Week 3	Integration on all the working modules	Integrate all the working modules of the project and perform a test run to check if the integration has been successfully implemented
Week 4	Output Generation	Generate all the required outputs and perform analysis to check the correctness of our forecasting model
Week 5	Model Testing	Testing and bug fixes
Week 6	Preparation of final deliverable	Preparing all the final project deliverable such as project report, presentation and working demo
Week 7	Final Demo and Presentation	Provide all the final deliverable

TABLE 3
Future Plan

to be submitted before final presentation and demo.

8 NOVELTY OF THE IDEA

Though there have been previous researches done in the field of parallel evolutionary algorithm [12], in this paper we have tried to overcome the time incurred by GA-FTS prediction model.

Also, with the advent of MapReduce [9] paradigm, it is much easier to abstract parallel system operations; while paving the way to

concentrate on the problem at hand. However, a restrictive programming model like MapReduce, requires the translation of the algorithm in the form of map/reduce functions. This is still a major challenge and needs to be done with much consideration.

9 POSSIBILITIES TO CONSIDER

During the execution of the project, the following will still be in consideration:

Can we dynamically retrieve data? Initially, we will be manually downloading/creating the

data.

[16] Apache Hama - <https://hama.apache.org/>

Can we use some other parallel framework? Possible candidates could be Spark [13], Storm [14], Giraph [15] or Hama [16]

Can we employ different MapReduce models of GA? Initially, only selection, crossover and mutation stages will be in reducer phase. We need to evaluate different mechanisms to improve the reduce phase.

Can we dynamically set thresholds for FTS/GA and number of individuals in GA? We will be manually tweaking these threshold values and visualizing the effects. We will try to have a dynamic way to sample training data and running multiple instance of the algorithm in parallel to decide appropriate threshold values.

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